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National Park Service
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The Development of a Long-Term Monitoring Protocol for the Coastal Lagoons of Cape Krusenstern National Monument

Pilot Sampling July 2009

Natural Resource Data Series NPS/ARCN/NRDS—2010/127

ON THE COVER
Kotlik Lagoon in Cape Krusenstern National Monument
Photograph by: Melinda Reynolds, 2009

The Development of a Long-Term Monitoring Protocol for the Coastal Lagoons of Cape Krusenstern National Monument

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Introduction

In 2007, the Arctic Network (ARCN) Inventory and Monitoring Program began the process of developing a monitoring protocol for coastal lagoons located in Cape Krusenstern National Monument (CAKR). Coastal lagoons are one of 28 vital signs selected for monitoring within ARCN parklands (Lawler et al. 2009). One of the primary goals of the National Park Service Inventory and Monitoring Program is to identify the status and trends of key natural resources, vital signs, found within the various parks. The intent of the monitoring program is to provide data that will assist resource managers in the decision-making process. Using monitoring data to make management decisions has long been a goal of CAKR and this strategy is clearly outlined in the General Management Plan (GMP) for Cape Krusenstern National Monument (1986), "…monitoring will be conducted so that thorough information about the condition of resources will be available to monument managers" (p. 7). More specifically, the GMP states the importance of monitoring water quality within the monument, "The National Park Service will establish a monitoring program…to provide baseline data on water quality of the monument against which future sampling can be compared" (p. 77). A water quality monitoring program, more specifically, a coastal lagoon monitoring program, has not been implemented at CAKR. Little park specific information exists for fish observations (Lentz et al. 2001). The ARCN has identified the need for a fish inventory. The lack of data hinders any decision-making processes, and is of particular concern because the area has been historically, and is currently, utilized for its abundance of subsistence fisheries resources.

The coastal lagoons in CAKR provide critical habitat for subsistence fishery resources, mainly whitefish (Uhl and Uhl 1977). Gillnets are placed in the sloughs of Krusenstern Lagoon during the summer in order to collect whitefish (personal observation). Fall, just before freeze-up, is also a critical season for fish harvesting. A unique harvest technique is practiced at Anigaaq, the outlet to Krusenstern Lagoon (Uhl and Uhl 1977; Georgette and Shiedt 2005). According to Uhl and Uhl (1977), "a simple three foot wide 'irrigation' ditch is dug in the porous gravel 20 feet long with a 10 foot diameter, circular 'stomach' on the end away from the edge of the water" (p. 11). This trench creates a current, making it attractive to the fish. The porous gravel cannot hold the water thus making it just about impossible for the fish to turn around and head back into the river. The "stomach" fills up with fish allowing for hundreds of fish to be harvested in this manner (Harris, pers comm.). According to Uhl and Uhl (1977), "…this is the major source of frozen winter whitefish for the residents of Kotzebue and Sisualik" (p. 12). This unique harvest technique continues today.

There are seven coastal lagoons located within the boundary of Cape Krusenstern National Monument: Akulaaq, Imik, Ipiavik, Kotlik, Krusenstern, Port, and Sisualik (Figure 1). Port Lagoon is the smallest (2 km^2) and Krusenstern Lagoon is the largest (56 km^2). The lagoons also vary in the amount of water exchange with the surrounding marine environment. Akulaaq, Krusenstern, and Sisualik are connected to Kotzebue Sound and Imik, Ipiavik, Kotlik, and Port are connected to Chukchi Sea. Akulaaq, Imik, Kotlik, and Port are all intermittently open. Krusenstern Lagoon is seasonally-closed at the mouth of the Tukrok River. The mouth of the Tukrok is opened in springtime as a result of ice breakup and the pushing of the ice down the river and out to the ocean. The mouth is closed in mid-July as gravel is pushed up by strong wave action resulting from strong storms. Sisualik and Ipiavik are open year-round. All lagoons have experienced an influx of seawater in response to strong westerly storms (personal observation).

Few studies have been conducted in the coastal lagoons of CAKR. Blaylock and Houghton (1983) collected abiotic and biotic data in Ipiavik and Port lagoons located within the CAKR boundary. Their study also included coastal lagoons north of the CAKR boundary. Schizas and Shirley (1994) conducted zooplankton research in Krusenstern Lagoon, and Reynolds et al. (2005) conducted physicochemical and biological sampling in five of the seven coastal lagoons located in CAKR. Determining the status and trends of these under-studied aquatic resources is not feasible given the minimal data that has been collected. As a result, making sound management decisions is difficult, at best.

What follows is the description of the pilot sampling project that took place in July 2009. The report documents the methods used and summarizes the data collected. This pilot sampling was completed to facilitate the development of the long-term monitoring protocol and standard operating procedures for the coastal lagoons vital sign. The results presented within this report are the result of preliminary analyses and should be treated as such.

Figure 1. Location of the seven coastal lagoons in Cape Krusenstern National Monument.

Objectives

Overall Objective

The overall objective of this project is to develop a long-term monitoring protocol for the coastal lagoons of CAKR for the Arctic Network Inventory and Monitoring Program. The vital signs to be monitored with this long-term monitoring protocol include: water quality, community composition (benthic, planktonic, and pelagic), and geomorphology.

In 2009, we tested the field sampling methods to determine the feasibility of sampling these remote ecosystems. Pilot sampling was conducted to refine standard operating procedures and to gain a better understanding of the logistical challenges involved in sampling such a remote area. More specifically, objectives were to: 1) collect physicochemical data in five lagoons (Akulaaq, Imik, Kotlik, Krusenstern, and Sisualik), 2) collect nutrient and chlorophyll *a* samples in five lagoons, 3) collect zooplankton samples in five lagoons, 4) collect benthic samples in three lagoons (Kotlik, Krusenstern, and Sisualik), and 5) collect pelagic species in three lagoons (Kotlik, Krusenstern, and Sisualik). These data, along with previously collected data (Reynolds et al. 2005), will be used to provide more information on variance as well as provide additional data for trend analysis.

Methods

As previously stated, the long-term monitoring protocol is currently under development and this pilot sampling was conducted in order to explore remote sampling techniques and gain a better understanding of logistical challenges. The methods employed here are subject to change.

Site Selection

Water Quality and Benthic and Planktonic Community

Within lagoon sampling locations were based on previous research conducted by Reynolds et al. (2005). Reynolds et al. (2005) sampling locations were chosen, in part, based on studies conducted by Blaylock and Houghton (1983), and Blaylock and Houghton (1983) selected their sampling locations based on the following four criteria: 1) near creek/river inlets and outlets, 2) in the middle of the lagoon, 3) along the shoreline-side of the lagoon, and 4) near any known anomalies (i.e. springs). Each lagoon has at least five sampling locations, with prior sampling locations included if possible. During pilot sampling in 2009 the sampling stations in the Reynolds et al. (2005) study were resampled. Utilizing the existing sampling sites will allow the data collected by Reynolds et al. (2005) to act as additional baseline information. The methods utilized in this pilot sampling were the same as those employed in the Reynolds et al. (2005) study to the extent possible.

Fish Community

Beach seine and experimental gill net sampling locations were based on accessibility and likelihood of capturing fish – thus the sampling is non-random and targeted. All nets were hauled or set in the littoral zone, where walking or anchoring onshore was possible. No gill nets were set in the middle of the lagoons. Sampling different strata (i.e. rocky bottom, soft bottom, shoreline-side, etc.) was accomplished if logistics and available sampling gear allowed. The pelagic fish community was minimally sampled during the pilot study. In the future we plan to monitor pelagic fishes in Kotlik, Krusenstern, and Sisualik.

Field Methods

Water Quality

This monitoring plan is focused on detecting long-term changes in the lagoon environments of CAKR. Sampling methods used to collect physicochemical data were based on the Environmental Protection Agency (EPA) National Coastal Assessment Field Operations Manual (U.S. EPA 2001). Adjustments were made to these protocols to incorporate already existing knowledge of the lagoon environments and to minimize logistical challenges.

Physicochemical data were measured in three lagoons (Akulaaq, Kotlik, and Krusenstern) July 22-28, 2009. We were unable to sample Imik, Kotlik, and Sisualik lagoons due to unforeseen logistical problems (see Discussion). At each sampling point (5-6 in each lagoon), the following core water quality parameters were measured in situ using a YSI multiparameter probe: water temperature, conductivity, and dissolved oxygen. Water depth and clarity were also measured at each site. Water depth was measured with the multiparameter probe and water clarity was measured with a Secchi disk off the side of the boat. The pH was determined back at the cabin using a Hanna Combo pH and EC meter (model # HI 98129). Total kjeldahl nitrogen (TKN), dissolved kjeldahl nitrogen (DKN), total kjeldahl phosphorus (TKP) and chlorophyll *a* were also measured at each site. To carry out these analyses, water samples were collected using a Niskin bottle, transferred to a plastic jug, sealed, placed in a cooler that was kept cold (ice packs in the cooler) and dark to protect degradation of chlorophyll *a*, and taken back to the cabin for processing.

Water was filtered under low light through glass-fiber filters (GF/F). Glass fiber filters were wrapped in aluminum foil and kept as cold as possible in the field, and stored frozen, until chlorophyll *a* analysis could be conducted. Three replicate filters were processed from each sampling location and the mean reported. The filtrate (500 ml) was placed in nalgene bottles and preserved with sulfuric acid, stored in a cooler with ice packs, placed in a refrigerator (4°C) once out of the field, and then shipped under cold storage to the laboratory for analysis. Filtrate samples were analyzed for dissolved kjeldahl nitrogen (DKN) back at the laboratory. Additional 500 ml aliquots of unfiltered water were placed in a nalgene bottles for subsequent determinations of total kjeldahl nitrogen (TKN) and total kjeldahl phosphorus (TKP) analysis. These samples were preserved with enough sulfuric acid to lower the pH of the sample to < 2 (APHA 1998), and kept cool. The nutrient samples were preserved with sulfuric acid according to Standard Methods (APHA 1998) as the freezing of samples is not an option due to the remote location and the extent of the sampling period.

Benthic and Planktonic Community

Benthic macroinvertebrate samples were collected at established water quality sampling sites in Kotlik, Krusenstern, and Sisualik. Protocols in the EPA National Coastal Assessment Field Operations Manual (2001) as well as those in Moulton II et al. (2002) were used to collect and preserve samples. Three replicates were taken at each sampling location with a petite ponar grab. Samples were sieved through a 500µm sieve over the side of the boat. Specimens were placed in nalgene bottles and preserved in 10% formalin and Rose Bengal once back at the cabin.

Zooplankton samples were collected at established water quality sampling sites in all the lagoons. A Fieldmaster 8-in diameter, 153µm mesh net was used to collect three, vertically depth-integrated tows (bottom to surface) at each sampling site. Samples were then preserved with 10% formalin once back at the cabin.

Fish Community

Pelagic fish sampling was conducted in Krusenstern Lagoon using both a beach seine and an experimental gill net (Figure 12). A 37-m bag beach seine was used to sample fish at one site in the lagoon. The beach seine was anchored on land using a pole, then two team members dragged the net perpendicular to the shore, and back to the beach in a U pattern. Fish were picked from the bag and net, identified, counted, measured, and returned to the water.

A 5-panel experimental gill net was used to collect larger, pelagic species. Gill nets were set at three sites in Krusenstern Lagoon (Figure 12). Each net consisted of 5 panels, each 25ft in length, for a total net length of 125ft. Stretch measurement of the individual panels were as follows: 1 inch, 1.5 inch, 2 inch, 3 inch, and 4 inch. The smallest mesh was anchored closest to shore, just off the beach and immersed in water and the largest mesh was anchored perpendicular to the shore. Each net was manned continuously in accordance with Alaska Department of Fish and Game permit requirements, so only one net could be deployed at a time. Krusenstern Lagoon, and associated waterways, are utilized by local residents in the harvest of subsistence fish species (Georgette and Schiedt 2005). To accommodate this important subsistence activity, we reduced the amount of time nets were set in the water in order to minimize our capture while still obtaining a representative sample. Each net was set for 1 hour. Captured fish were identified, measured, and released as quickly as possible to minimize the amount of fish mortality.

Laboratory Methods

Water Quality

Nutrient and chlorophyll *a* samples were shipped to the Central Environment Laboratory at East Carolina University for analysis. Nutrient samples (DKN, TKN, and TKP) were processed with methods found in Standard Methods for the Examination of Water and Wastewater (APHA 1998). Chlorophyll *a* and phaeophytin analyses were processed using spectrophotometric analysis following methods described in Standard Methods for the Examination of Water and Wastewater (APHA 1998), Parsons et al. (1984), and Strickland and Parsons (1968). The corrected chlorophyll *a* concentration was reported and used to indicate algal biomass. Phaeophytin, a breakdown product of chlorophyll, was also calculated as a means to help indicate the health of the algal community; it is the ratio of chlorophyll to phaeophytin that provided this information.

Benthic and Planktonic Community

Benthic and zooplankton samples were shipped to East Carolina University for analysis. Samples will be identified to the lowest possible taxon, but had not been processed by the time the report was published.

Results

Water Quality

We were unable to sample Imik and Sisualik due to logistical challenges including weather, boat problems, time constraints, and lagoon accessibility. We were able to sample Akulaaq, Krusenstern, and one site in Kotlik Lagoon for water quality parameters.

Akulaaq Lagoon

Physicochemical data were collected at all five sampling points in Akulaaq Lagoon (Figure 2). We only collected a surface sample (0.5m) because the lagoon is < 2m in depth. Figure 3 and Figure 4 demonstrate that there was little site-to-site variability. Each of the four core parameters were within 2 standard deviations of their mean, which was calculated by averaging all sites within the lagoon. The mean and standard deviation for each parameter were as follows: water temperature (16.18 C ± 0.20), salinity (15.26 ppt ± 0.09), dissolved oxygen (14.05 mg/L ± 0.75), and pH (8.22 ± 0.28) (Figure 21). There was also minimal variability in the nutrient levels between sites as all sites were within 2 standard deviations of the mean (Figure 5). Again, a mean for the lagoon was calculated by averaging all the sites. Mean and standard deviation for each nutrient were as follows: DKN (0.69 mg/L ± 0.06), TKN (1.12 mg/L ± 0.19), and TKP (0.12 mg/L ± 0.02) (Figure 22). Chlorophyll *a* varied among sites, with AU4 having the highest chlorophyll *a* concentration with 21.95 μg/L and AU2 having the highest phaeophytin concentration with 8.37 μg/L (Figure 6).

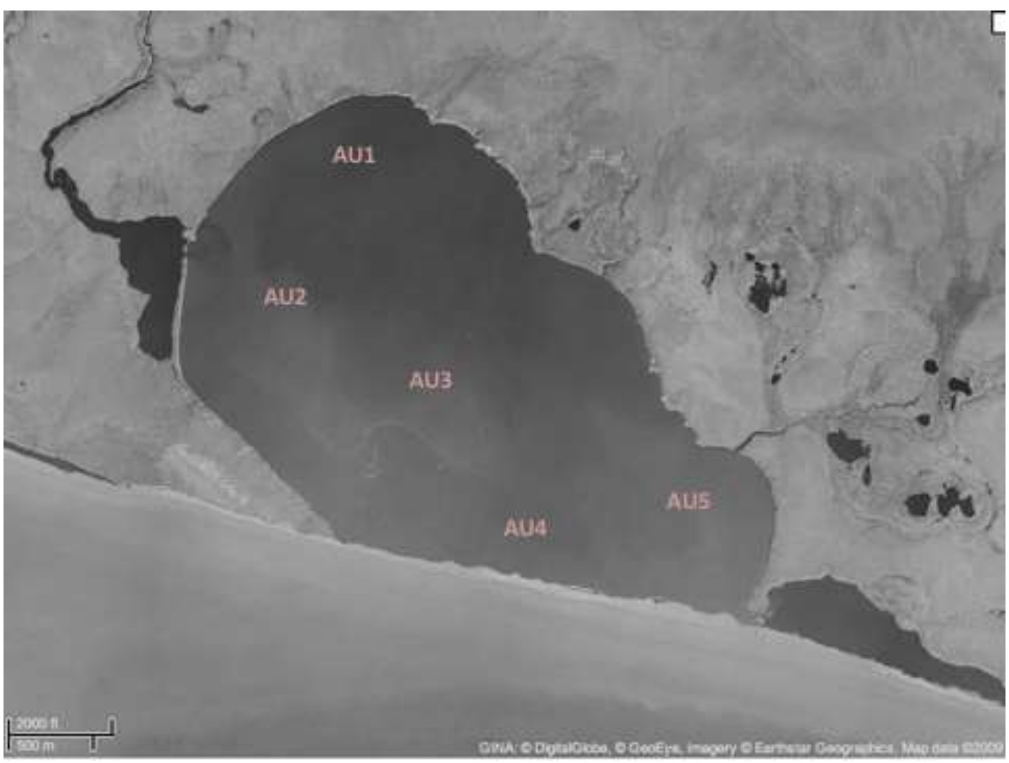

Figure 2. The location of the five sampling points in Akulaaq Lagoon. Water quality parameters were measured at all five sites in July 2009.

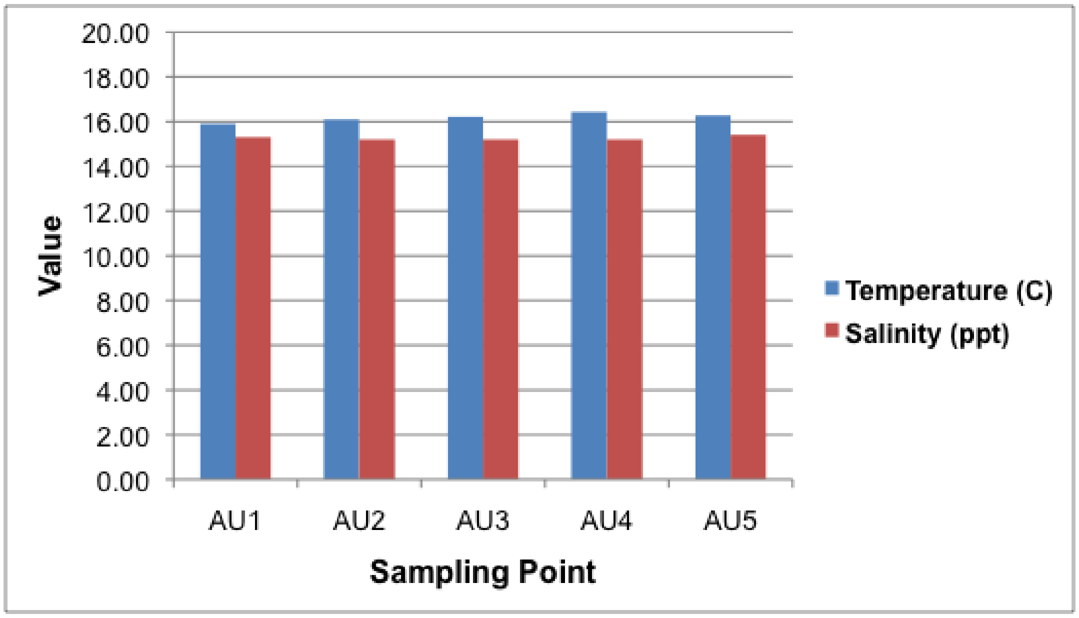

Figure 3. Temperature and salinity data for five sampling points in Akulaaq Lagoon, July 2009. Only a surface sample (0.5m) was collected as the lagoon is < 2m in depth.

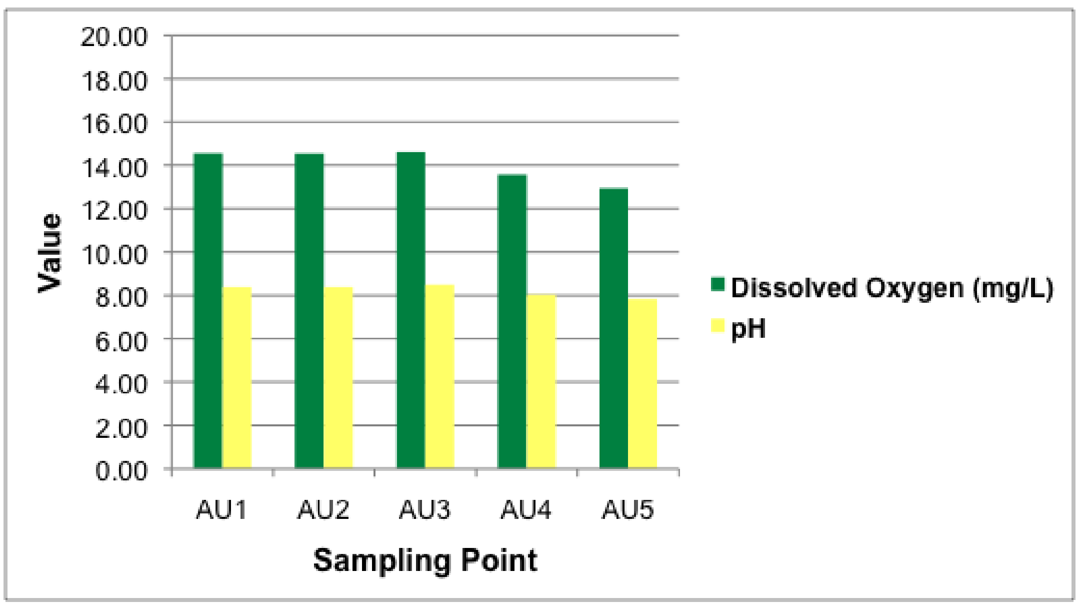

Figure 4. Dissolved oxygen and pH data for five sampling points in Akulaaq Lagoon, July 2009. Only a surface sample (0.5m) was collected as the lagoon is < 2m in depth.

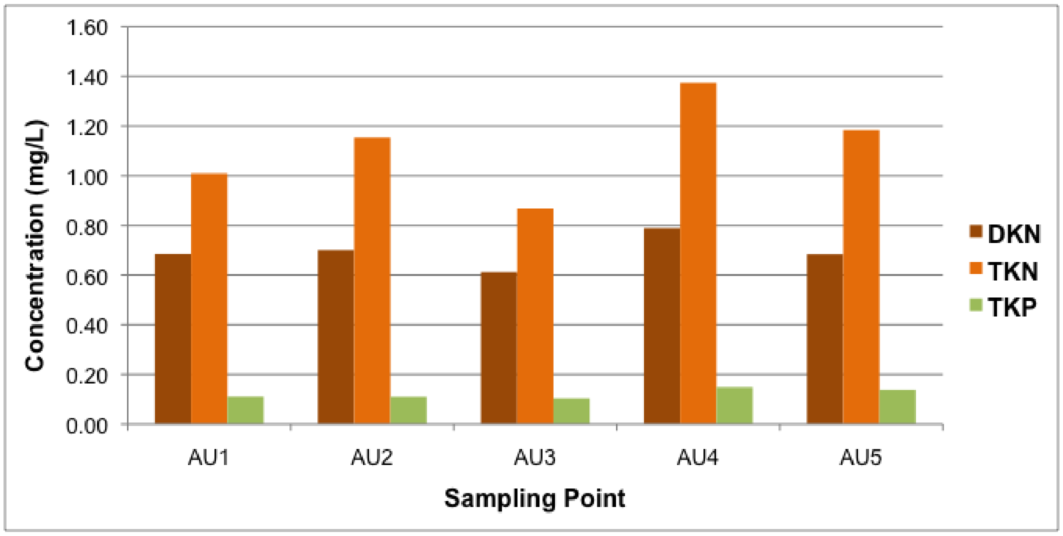

Figure 5. Nutrient data for the five sampling points in Akulaaq Lagoon, July 2009. Each site was analyzed for DKN, TKN, and TKP.

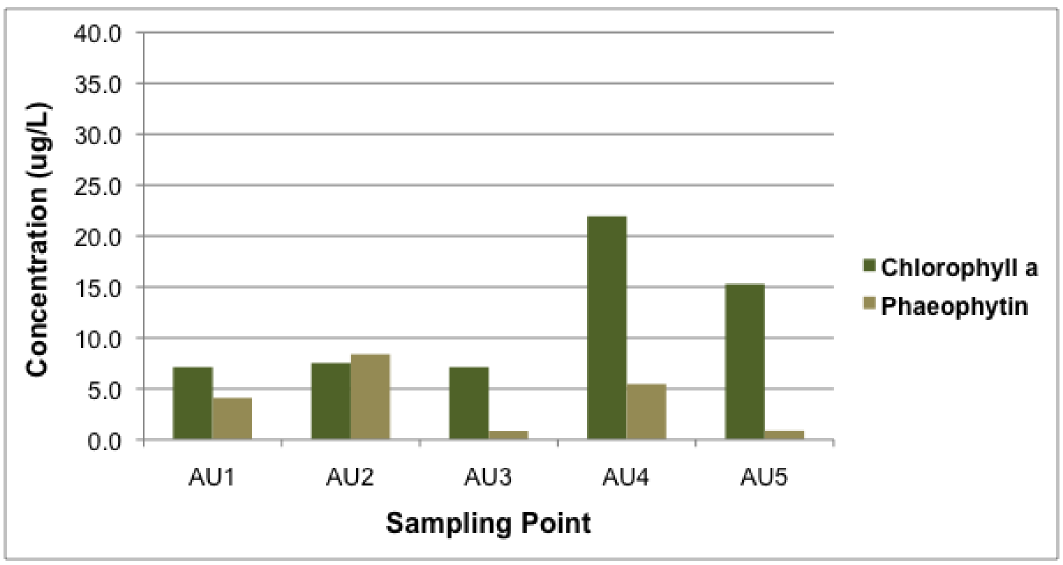

Figure 6. Pigment data for the five sampling points in Akulaaq Lagoon, July 2009. Each site was analyzed for Chlorophyll *a* and Phaeophytin. The corrected chlorophyll *a* data are reported.

Kotlik Lagoon

Physicochemical data were collected at only one site in Kotlik Lagoon (Figure 7). Only a surface sample was collected because the lagoon is < 2m in depth at that location. An explanation for only one sampling site can be found in the discussion section of this report. The four core parameters measured as follows at KO6: temperature (14.62 C), salinity (13.60 ppt), dissolved oxygen (13.95 mg/L), and pH (7.71) (Figure 8 and 9). In terms of nutrients, DKN was 0.40 mg/L, TKN was 1.46 mg/L, and TKP was 0.25 mg/L (Figure 10). Chlorophyll *a* concentration was 21.60 μg/L and phaeophytin concentration was 10.53 μg/L (Figure 11).

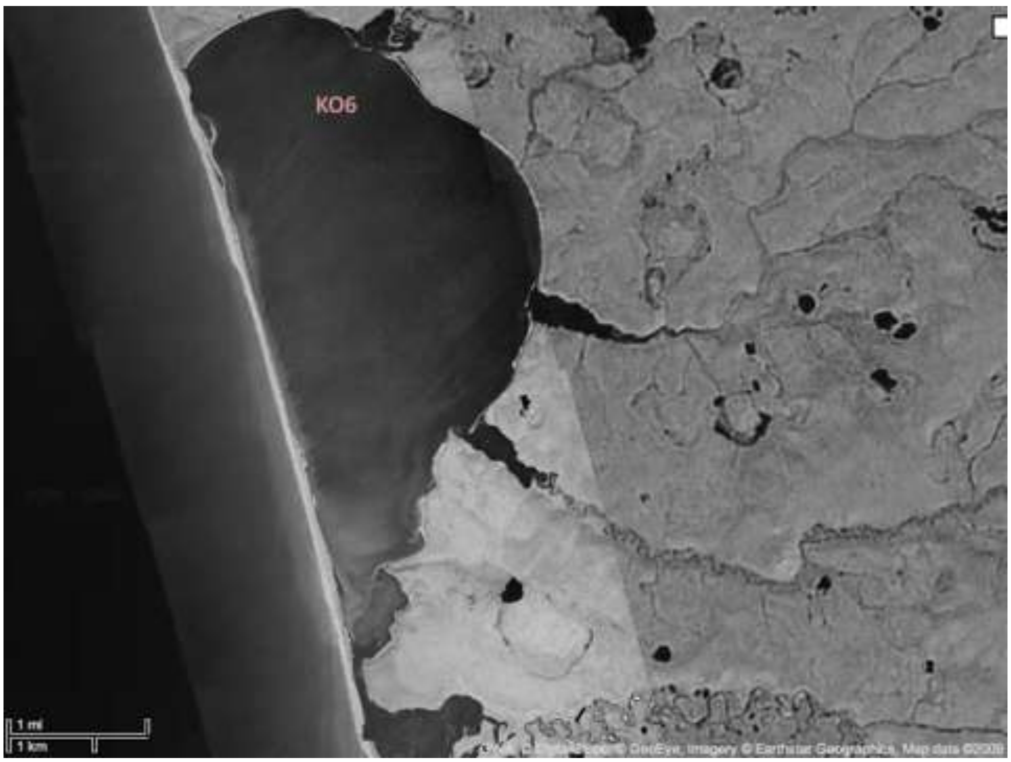

Figure 7. The location of the only sampling point in Kotlik Lagoon, July 2009. Five more sampling points were planned, but weather and other logistical issues prevented the collection of data at those sites during this sampling period.

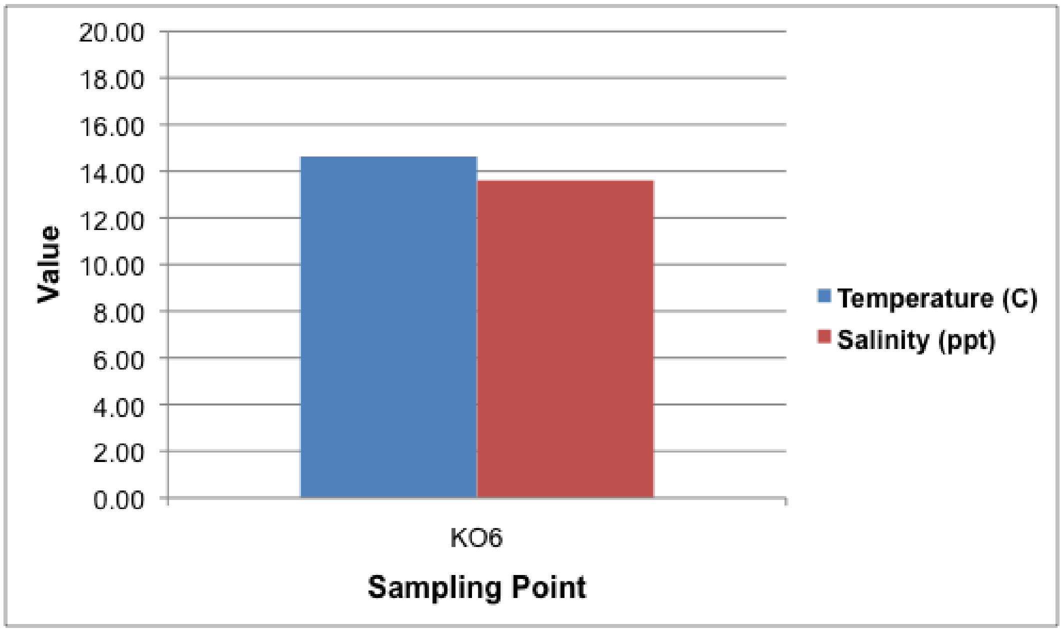

Figure 8. Temperature and salinity data for sampling point KO6 in Kotlik Lagoon, July 2009. The lagoon is < 2m in depth so only a surface sample was collected.

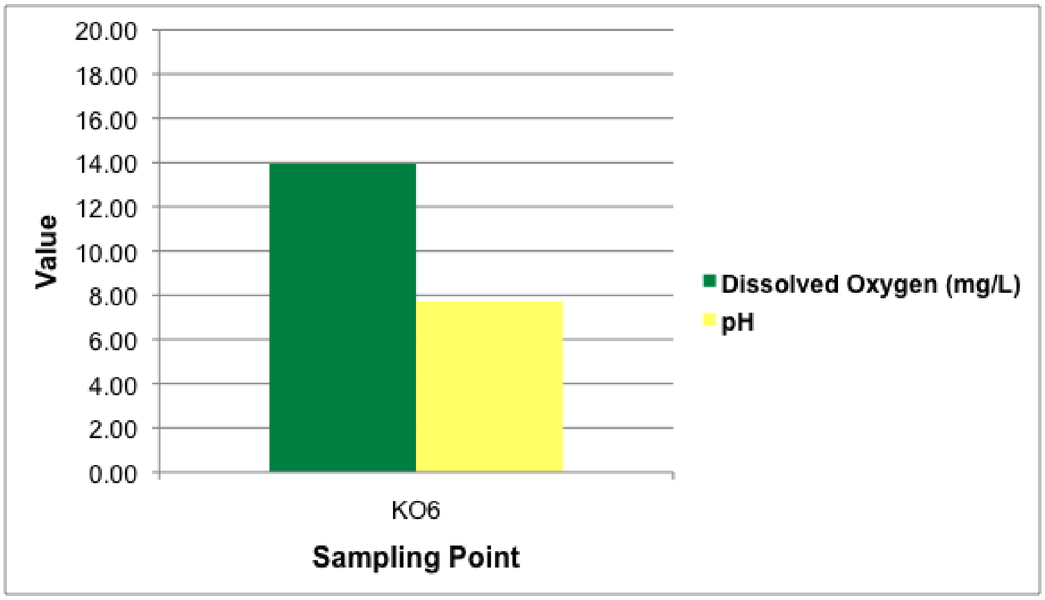

Figure 9. Dissolved oxygen and pH data for sampling point KO6 in Kotlik Lagoon, July 2009. The lagoon is < 2m in depth so only a surface sample was collected.

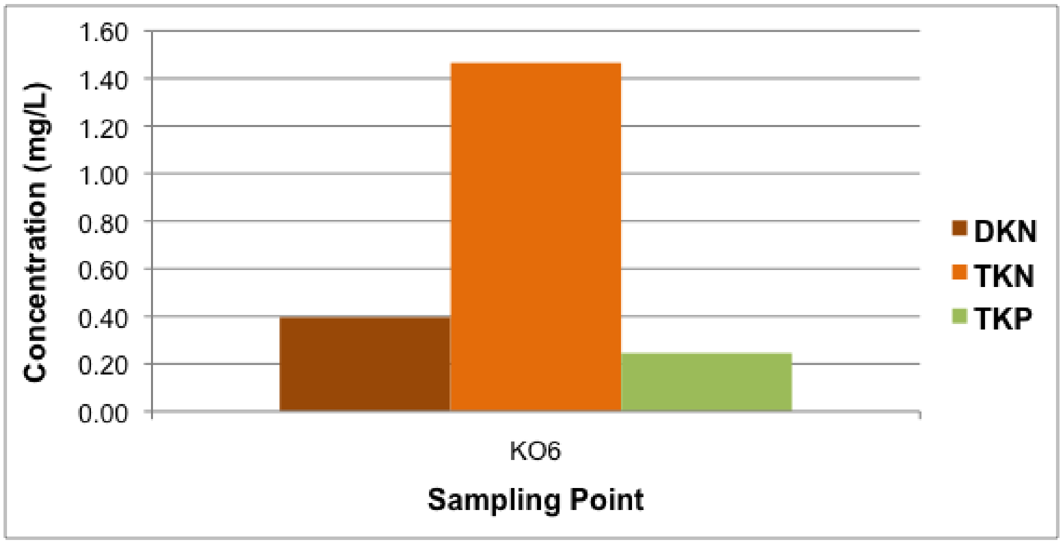

Figure 10. Nutrient data for one sampling point in Kotlik Lagoon, July 2009. DKN, TKN, and TKP were analyzed from the surface sample.

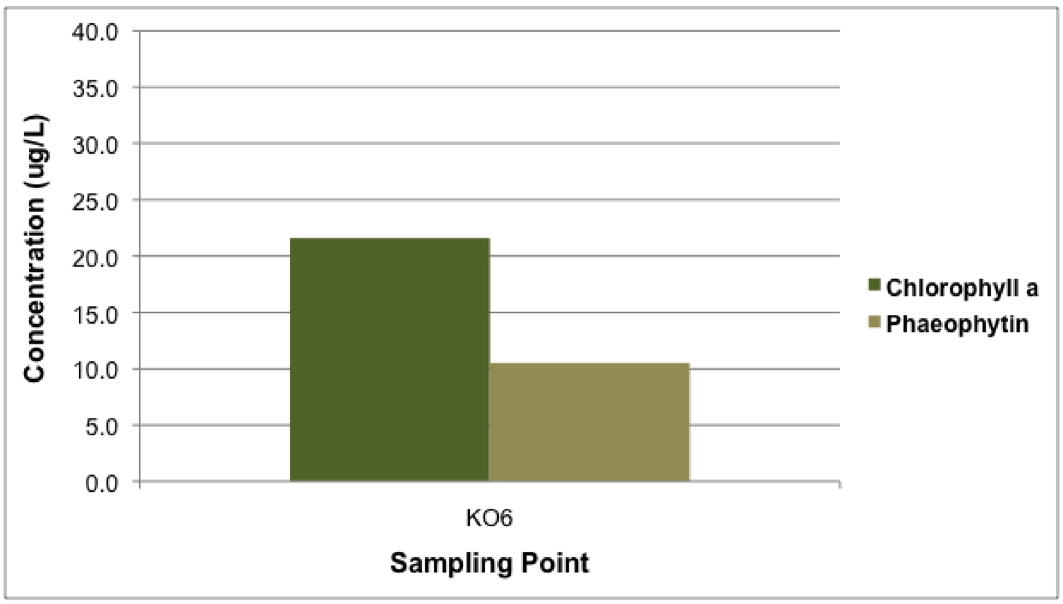

Figure 11. Chlorophyll a and phaeophytin data for the one sampling point in Kotlik Lagoon, July 2009. Both chlorophyll a and phaeophytin concentrations were measured from the surface sample. The corrected chlorophyll a data are reported in the graph.

Krusenstern Lagoon

Physicochemical data were collected at all six sampling locations in Krusenstern Lagoon (Figure 12). Both surface (0.5m) and bottom (0.5m off bottom) samples were collected at each site because the lagoon is > 2m in depth. The data show that there is no stratification (difference between the top and bottom sample) within the water column and that there is minimal variability among sites (Figures 13-16). All surface samples were averaged and the mean and standard deviation for the core parameters were as follows: temperature (17.82 C ± 0.82), salinity (5.77 ppt ± 0.15), dissolved oxygen (13.60 mg/L ± 0.47), and pH (8.92 ± 0.16) (Figure

21). All bottom samples were averaged and the mean and standard deviation for the core parameters were as follows: temperature (17.50 C ± 0.81), salinity (5.75 ppt ± 0.10), dissolved oxygen (13.29 mg/L ± 0.53), and pH (9.01 ± 0.12) (Figure 21). All surface and bottom samples were within 2 standard deviations of the mean. In terms of nutrients, all surface samples were averaged and the mean and standard deviation were as follows: DKN (0.53 mg/L ± 0.06), TKN (1.15 mg/L ± 0.19), and TKP (0.08 mg/L ± 0.02) (Figure 22). All surface samples were within 2 standard deviations of the mean. Bottom sample mean and standard deviation were as follows: DKN (0.48 mg/L ± 0.04), TKN (1.17.mg/L ± 0.16), and TKP (0.09 mg/L ± 0.02) (Figure 22). All sites were within 3 standard deviations of the mean. Chlorophyll a concentrations were also highest at KR2. The surface sample had a concentration of 37.99 µg/L and the bottom sample had a concentration of 39.44 µg/L (Figure 19 and Figure 20). Phaeophytin concentration in the surface samples was highest at KR3 with a concentration of 7.94 µg/L and in the bottom samples, it was highest at KR2 with a concentration of 7.29 µg/L (Figure 19 and Figure 20).

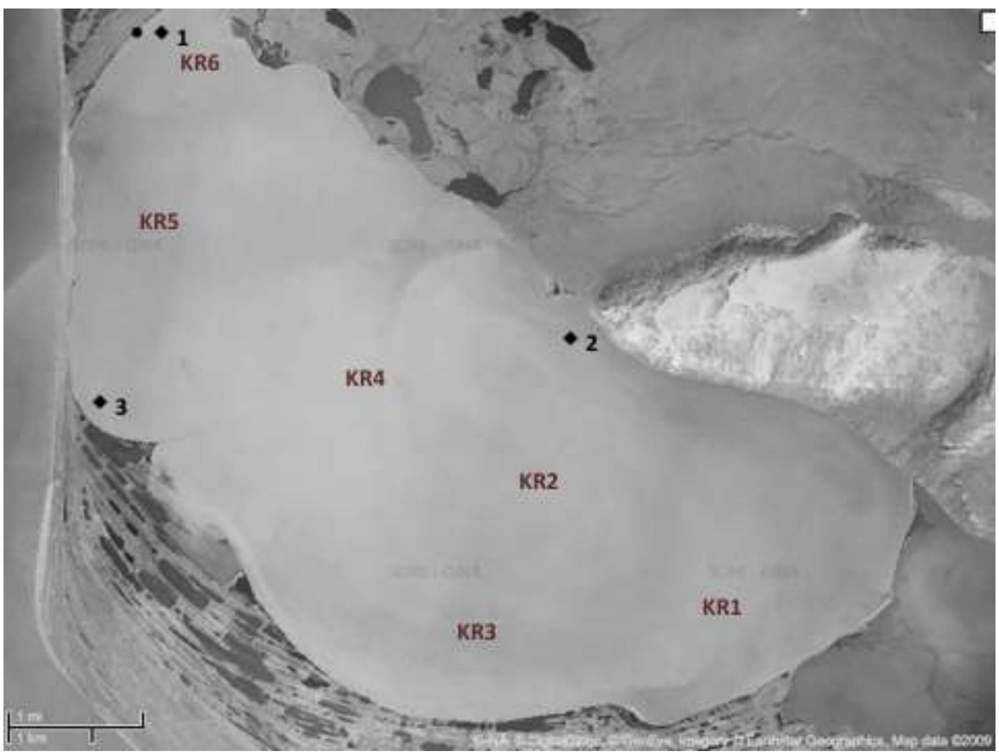

Figure 12. The location of the six physicochemical sampling points in Krusenstern Lagoon (KR1 – KR6). Water quality parameters were measured at all six sites in July 2009. Experimental gill net (♦) and beach seine (•) locations are also represented on the map.

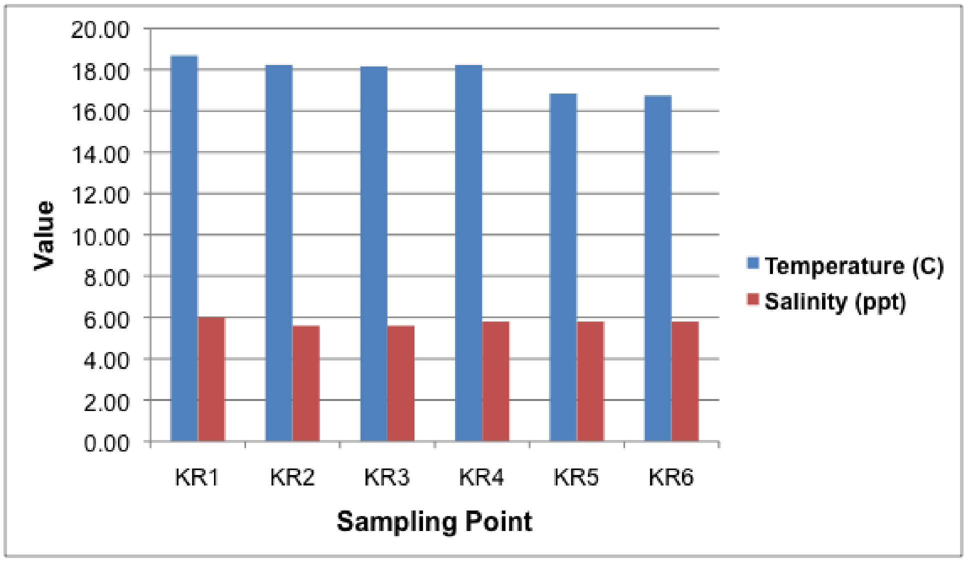

Figure 13. Surface temperature and salinity data for six sampling points in Krusenstern Lagoon, July 2009.

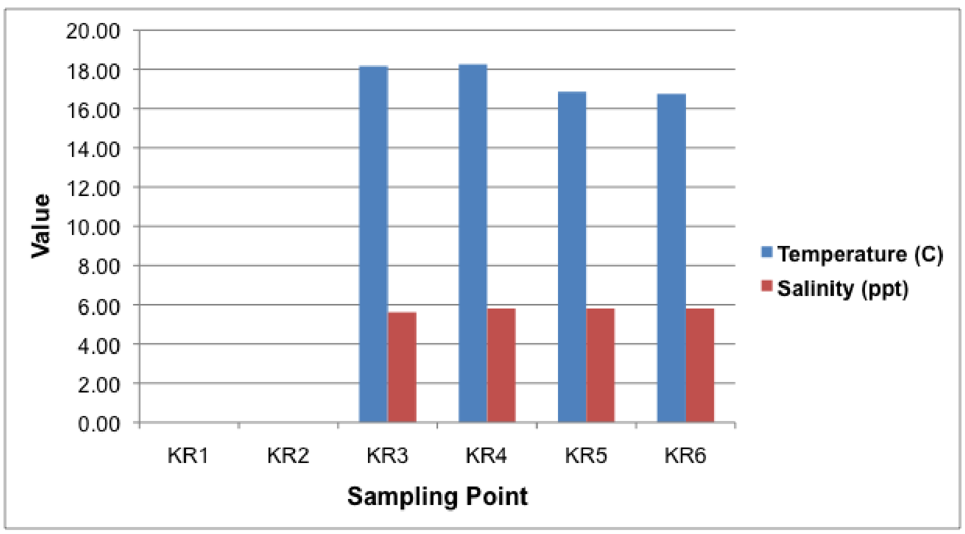

Figure 14. Bottom temperature and salinity data for six sampling points in Krusenstern Lagoon, July 2009. Data at sites KR1 and KR2 are not shown because mud collected on the probe as it hit the bottom.

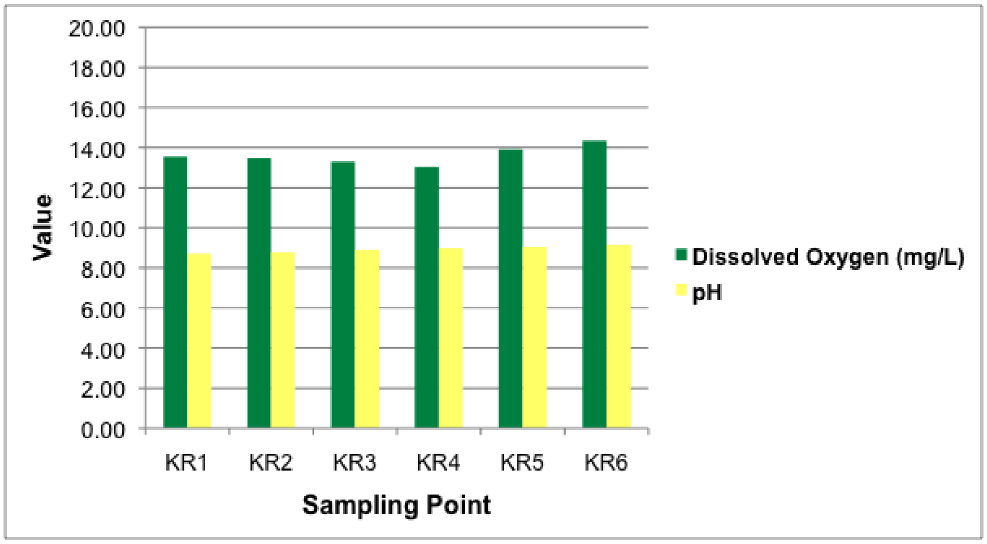

Figure 15. Surface dissolved oxygen and pH data for six sampling points in Krusenstern Lagoon, July 2009.

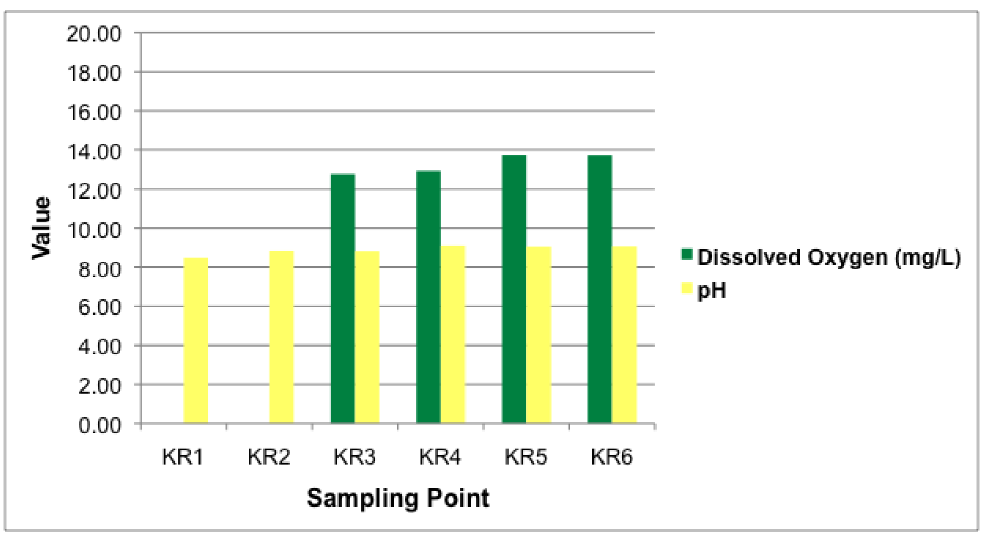

Figure 16. Bottom dissolved oxygen and pH data for six sampling points in Krusenstern Lagoon, July 2009. Data at sites KR1 and KR2 are not shown because mud collected on the probe as it hit the bottom.

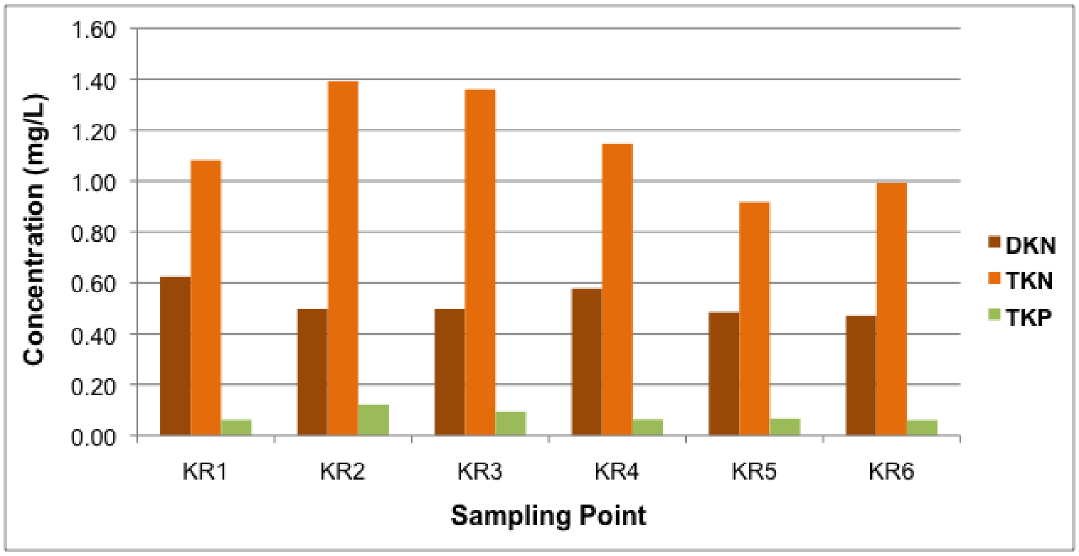

Figure 17. Surface nutrient data for the six sampling points in Krusenstern Lagoon, July 2009. Each site was analyzed for DKN, TKN, and TKP.

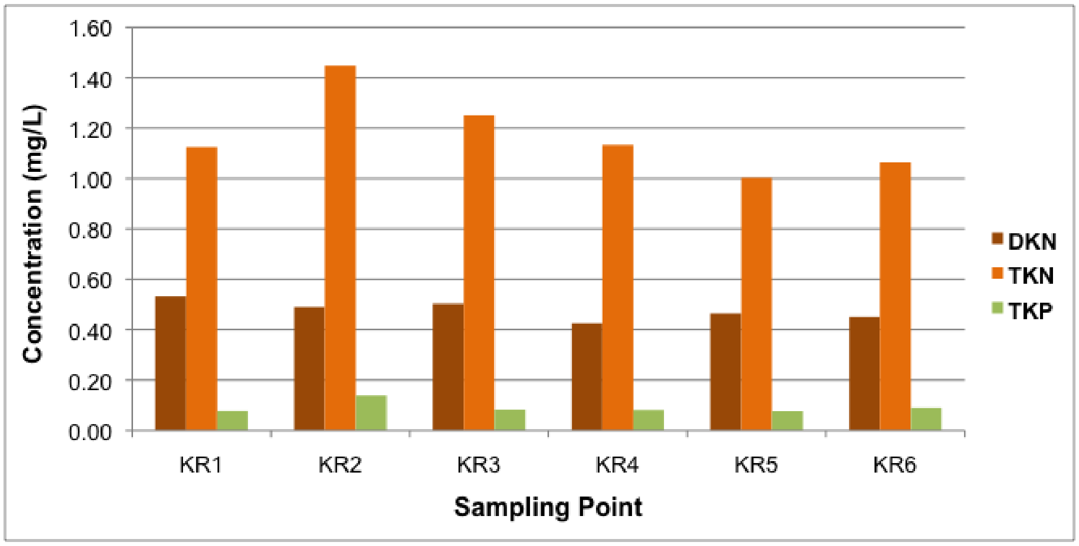

Figure 18. Bottom nutrient data for the six sampling points in Krusenstern Lagoon, July 2009. Each site was analyzed for DKN, TKN, and TKP.

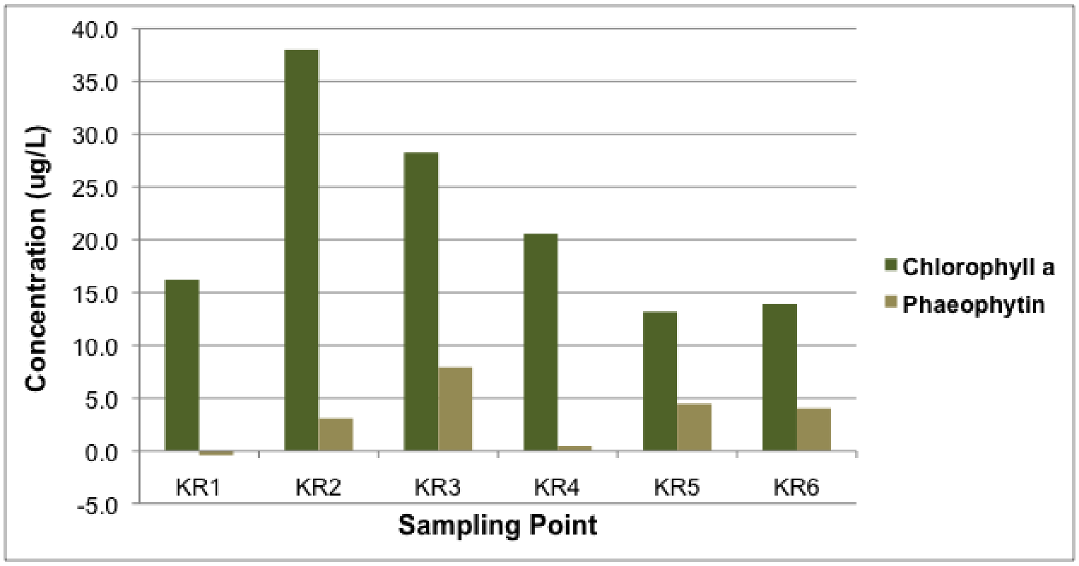

Figure 19. Surface pigment data for the six sampling points in Krusenstern Lagoon, July 2009. Both chlorophyll *a* and phaeophytin concentrations were measured. The corrected chlorophyll *a* data are reported in the graph.

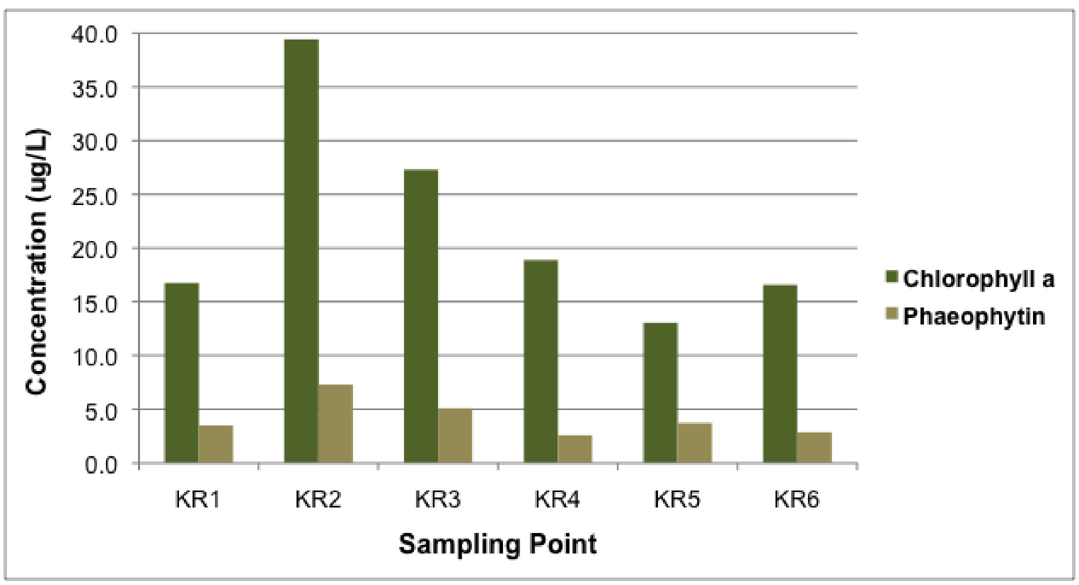

Figure 20. Bottom pigment data for the six sampling points in Krusenstern Lagoon, July 2009. Both chlorophyll *a* and phaeophytin concentrations were measured. The corrected chlorophyll *a* data are reported in the graph.

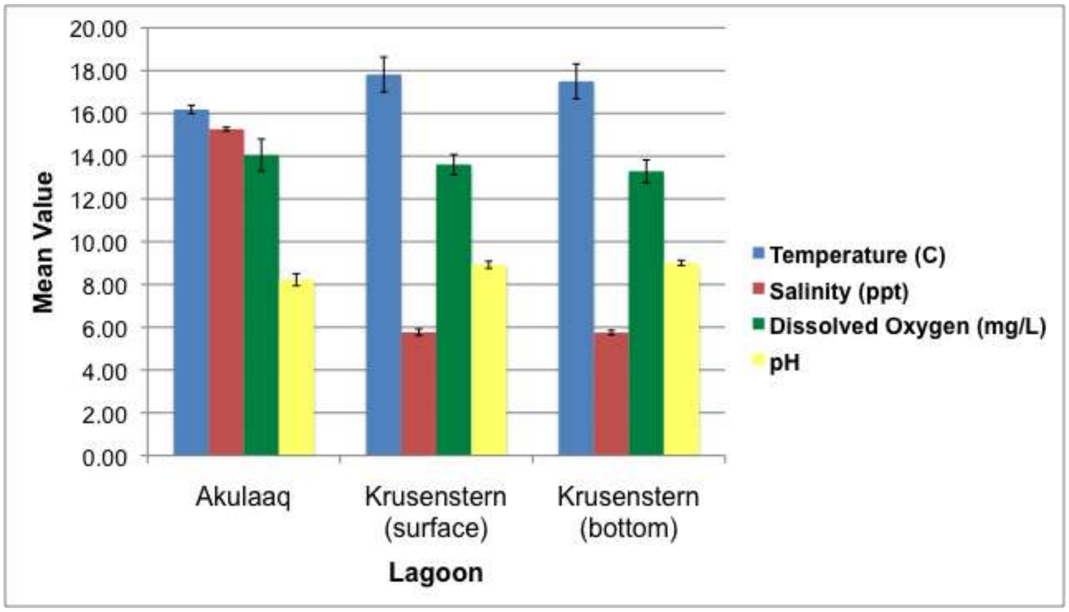

Figure 21. Mean values for temperature, salinity, dissolved oxygen, and pH for each lagoon in July 2009. Error bars represent ± 1 standard deviation.

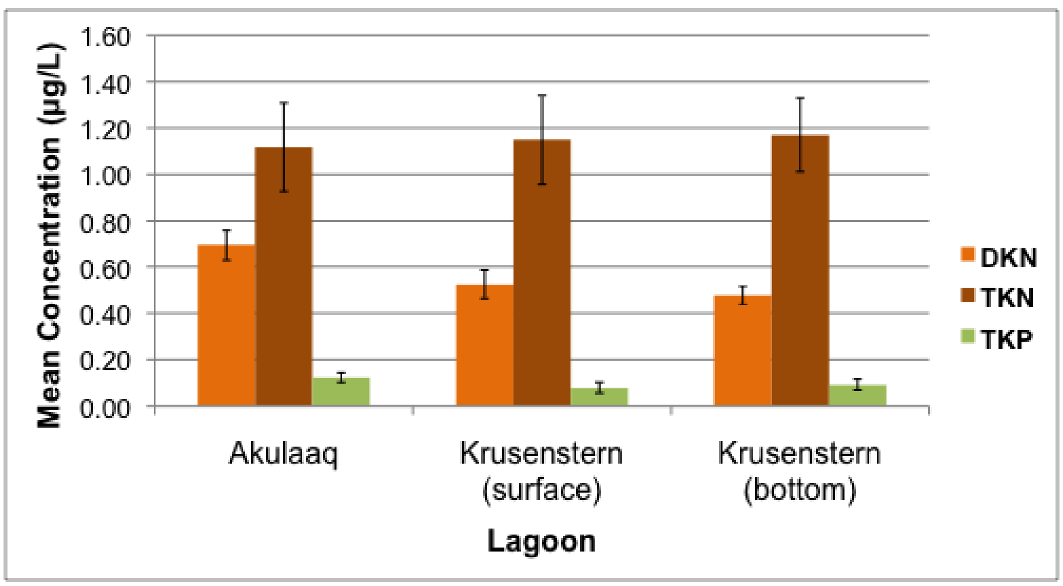

Figure 22. Mean values for DKN, TKN, and TKP for each lagoon in July 2009. Error bars represent ± 1 standard deviation.

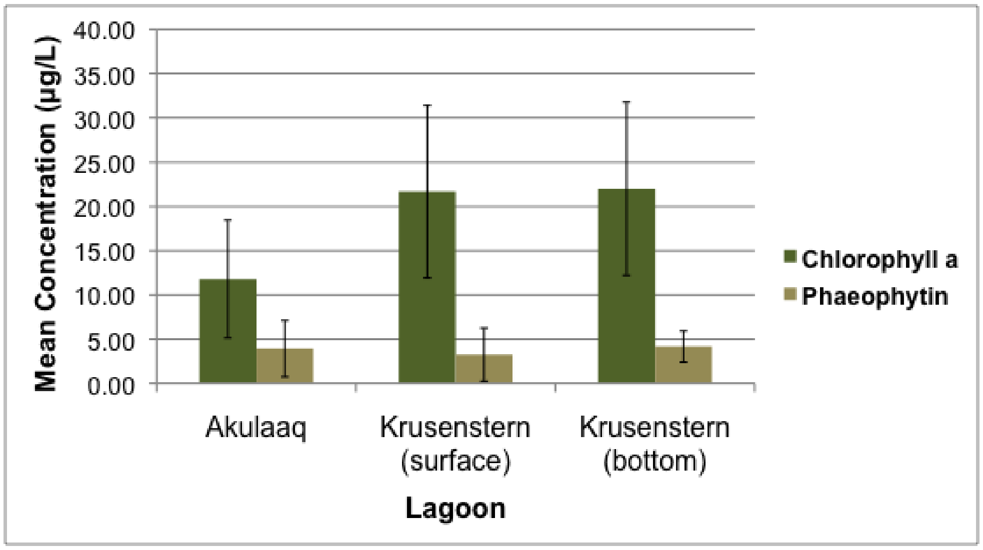

Figure 23. Mean values for chlorophyll *a* and phaeophytin for each lagoon in July 2009. Error bars represent ± 1 standard deviation. The corrected chlorophyll *a* data are reported in the graph.

Benthic and Planktonic Community

Benthic samples were collected at all six water quality sampling sites in Krusenstern Lagoon (Figure 12). Three replicates were collected at each site. Samples are currently at the lab and are scheduled to be sorted and identified by December 2010.

Zooplankton samples were collected at all water quality sampling sites in Akulaaq Lagoon and Krusenstern Lagoon. Three replicates were collected at each site. Samples are currently at the lab and data will be available in December 2010.

Fish Community

The beach seine was hauled one time, in one location, in Krusenstern Lagoon (Figure 12). More than 100 ninespine sticklebacks (*Pungitius pungitius*) were collected during the haul (Table 1).

The 5-panel experimental gill net was set three times, for one hour per set. Nets were set in three different locations, in Krusenstern Lagoon (Figure 12). At location 1, no fish were collected after the 1-hour time limit. We caught 5 fish at location 2, which resulted in a catch-per-unit-effort (CPUE) of 1 fish/panel-hour. At location 3, we caught 8 fish, which calculated to a CPUE of 1.6 fish/panel-hour. A total of 13 fish were caught in the lagoon, representing 5 different species, (Table 1).

Table 1. Pelagic species collected in Krusenstern Lagoon, July 2009. Nets were hauled or set once at each location (see Figure 12 for net locations).

Lagoon	Location	Haul or Set Number	Collection Method	Scientific Name	Common Name	Total Length (mm)	Notes
Krusenstern	1	1	Beach Seine	*Pungitius pungitius*	Ninespine Stickleback	26-35	> 100 collected
Krusenstern	1	1	Sinking 5-Panel Experimental Gill Net	-	-	0	Net Set for 1 Hour No Fish Collected
Krusenstern	2	1	Sinking 5-Panel Experimental Gill Net	*Stenodus leucichthys*	Sheefish	680	Net Set for 1 Hour
Krusenstern	2	1	Sinking 5-Panel Experimental Gill Net	*Coregonus pidschian*	Humpback Whitefish	430	
Krusenstern	2	1	Sinking 5-Panel Experimental Gill Net	*Coregonus pidschian*	Humpback Whitefish	440	
Krusenstern	2	1	Sinking 5-Panel Experimental Gill Net	*Coregonus pidschian*	Humpback Whitefish	350	
Krusenstern	2	1	Sinking 5-Panel Experimental Gill Net	*Coregonus pidschian*	Humpback Whitefish	390	
Krusenstern	3	1	Sinking 5-Panel Experimental Gill Net	*Coregonus sardinella*	Least Cisco	310	Net Set for 1 Hour
Krusenstern	3	1	Sinking 5-Panel Experimental Gill Net	*Coregonus sardinella*	Least Cisco	305	
Krusenstern	3	1	Sinking 5-Panel Experimental Gill Net	*Clupea pallasii*	Pacific Herring	215	
Krusenstern	3	1	Sinking 5-Panel Experimental Gill Net	*Clupea pallasii*	Pacific Herring	185	
Krusenstern	3	1	Sinking 5-Panel Experimental Gill Net	*Coregonus pidschian*	Humpback Whitefish	385	
Krusenstern	3	1	Sinking 5-Panel Experimental Gill Net	*Coregonus pidschian*	Humpback Whitefish	325	
Krusenstern	3	1	Sinking 5-Panel Experimental Gill Net	*Coregonus pidschian*	Humpback Whitefish	420	
Krusenstern	3	1	Sinking 5-Panel Experimental Gill Net	*Gasterosteus aculeatus*	Threespine Stickleback	100	

Discussion

Sampling Results

This report is a summary of the pilot sampling that was conducted in the coastal lagoons of Cape Krusenstern National Monument in July 2009. Pilot sampling was conducted to refine the standard operating procedures being developed for coastal lagoons. The primary objectives were to develop and refine sampling protocols, get a better understanding of the logistical restraints of the sampling methods, and to collect data on the physical, chemical and biological factors.

After reviewing the core water quality parameter data, it is apparent that site-to-site differences in Akulaaq (Figures 3 & 4) and Krusenstern (Figures 13-16) are minimal. The data demonstrate that there is no stratification within the water column in Krusenstern Lagoon. Krusenstern is deeper than Akulaaq so it is highly probable that Akulaaq is well mixed as well. Both lagoons also exhibit high dissolved oxygen levels (Figures 4, 15, 16). The frequent high winds and shallow lagoon depths are the likely explanations for the well-mixed water columns and their high dissolved oxygen concentrations.

The mean salinity for Akulaaq Lagoon was 15.26 ppt and the mean salinity for Krusenstern Lagoon was 5.77 ppt. These differences in salinity can partially be attributed to the direct influx of seawater. Akulaaq is intermittently open and at the time of sampling, there was a breach at the south-end of the lagoon, where Kotzebue Sound water was directly entering the lagoon. Krusenstern has a more indirect connection to the Sound. The Tukrok River flows out of the lagoon, travels approximately 10 km through winding sloughs, before it reaches Kotzebue Sound. The salinity in Krusenstern Lagoon is more likely due to indirect sources, such as ocean spray and underground seawater seeps along its coastal margins.

The limited nutrient data presented here demonstrate that in both Akulaaq and Krusenstern, nitrogen is the limiting nutrient. This determination is based on the Redfield Ratio of 16:1 (N:P) (Redfield 1958). More nutrient data are needed to support this conclusion. The chlorophyll *a* and phaeopigment concentrations in both Akulaaq and Krusenstern had high site-to-site variability (Figure 23). In Akulaaq, sites AU4 and AU5 had the highest concentrations (Figure 6). These stations are located closest to one of the breaching points, at the south-end of the lagoon. At the time of sampling, this breaching point was open and Kotzebue Sound water was freely flowing into the lagoon. In Krusenstern, the data again demonstrate that the water column is well mixed as the surface and bottom concentrations of chlorophyll *a* and phaeophytin are similar (Figures 19 and 20). Using the chlorophyll data as a proxy for algal biomass, these data suggest that the algal biomass in both of these lagoons is high. The ratio of chlorophyll *a* to phaeophytin further describes the algal community in these systems. Because phaeophytin is a breakdown product of chlorophyll, the ratio can act as an indicator of the health of the algal community. The data presented here show that this ratio is smallest in Akulaaq, indicating that the algal community in Akulaaq is more degraded than the community in Krusenstern. These data show that the algal community in Krusenstern has more active growth when compared with Akulaaq (Figure 23).

In terms of the biotic community, zooplankton samples were collected at all sites in Akulaaq and Krusenstern, but are currently at the lab and have not been identified yet. Benthic samples were collected from the six sites (Figure 12) in Krusenstern, but have yet to be sorted and identified. Only one beach seine haul was conducted in Krusenstern Lagoon. The decision was made in the field to stop using the seine because it was too large and cumbersome (37-m net) for the field crew to use and transport to multiple sites. A smaller, 50 ft seine has been ordered for future sampling. Few experimental gillnets were set in Krusenstern as a result of the logistical challenges discussed herein, but the fish collected during this sampling period represented five different species and were of harvestable size. The catch data presented here, along with local knowledge, suggest this lagoon is rich in subsistence fisheries resources. More nets should be set in various locations in order to calculate a mean CPUE for the entire lagoon. This information will provide not only presence/absence data, but also relative abundance through the use of CPUE data.

Logistical Challenges

The initial objective of the project was to visit five of the coastal lagoons (Akulaaq, Imik, Kotlik, Krusenstern, and Sisualik). Physicochemical data were to be collected in all the lagoons and benthic and fish community data were to be collected in Krusenstern, Kotlik, and Sisualik. Unfortunately, we were unable to visit all of the lagoons we were planning to sample. We were successful in completely sampling all sites in Akulaaq and Krusenstern lagoons, along with only one sample from Kotlik Lagoon. Akulaaq was sampled with a zodiac raft and in Krusenstern Lagoon, the sampling sites were accessed and nets were deployed using an aluminum Lund boat. The sample from Kotlik was collected from a floatplane while winds were blowing $\geq$ 20mph. The pilot was able to fly up to the lagoon to allow for the collection of one sample before heading back to Kotzebue.

A combination of weather, boat problems (i.e. mechanical problems), and lagoon access prevented us from collecting data at all our planned sites. We were unsuccessful in sampling Imik, much of Kotlik, and Sisualik. Faced with these logistical challenges, the sampling team decided to forego sampling at Imik and Kotlik in order to try to complete the sampling at Akulaaq and Krusenstern. Sampling at Sisualik did not occur due to the opening of the Tukrok River at Anigaaq. This river outflow is usually closed up by strong westerly storms in mid July as gravel is pushed up, causing the closing of the river. Once we were onsite, the opening was revealed to us and it was obvious it was too deep to drive fourwheelers through in order to continue down the beach to Sisualik. Future sampling events will require a check of the coastline to identify any openings/crossings that may be encountered if traveling the beach via fourwheeler is planned.

Future Sampling / Recommendations

The lessons learned and new insights from this pilot sampling will be considered as the long-term monitoring plan for the coastal lagoons of CAKR is developed. The sample design in the long-term monitoring protocol is a revisit sample design so perhaps another option for carrying out the sampling is to sample all the lagoons from a floatplane when only water quality samples are to be collected. In this design, physicochemical samples are scheduled to be collected every year. The use of a floatplane for sampling will depend highly on the weather as wind is a normal occurrence along the coast. The use of a floatplane for sampling is also water depth-dependent. These lagoons are very shallow and may not accommodate floatplane landings. If sampling from a floatplane proves feasible then standard operating procedures for sampling from a floatplane will have to be developed. In this revisit design, fish sampling is scheduled to take place every five years. This means a team will have to be on the ground to conduct the sampling at this five-year interval.

The following are recommendations for future sampling events: 1) more nets should be hauled and set in Krusenstern Lagoon (as well as in Kotlik and Sisualik), 2) access to both Imik and Kotlik must be via floatplane, perhaps with a base camp at Kotlik and a fourwheeler trip up to Imik, and 3) schedule a fly-by to check the river opening at Anigaaq if ground-sampling is to occur at Akulaaq and Sisualik, with a base camp at the Anigaaq ranger station.

The data collected during this pilot sampling, along with those data collected during previous work conducted by Reynolds et al. (2005), demonstrate that these coastal lagoons are dynamic ecosystems (personal observation). Monitoring the long-term trends of these arctic systems will provide insight into these under-studied ecosystems. And with climate change and the exploration of gas and oil in the Chukchi Sea and surrounding lands, the monitoring of these arctic, coastal, aquatic resources has never been more paramount.

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